

Houses as ATMs?

Mortgage Refinancing and Macroeconomic Uncertainty

Preliminary and incomplete*

Hui Chen
MIT Sloan and NBER

Michael Michaux
USC Marshall

Nikolai Roussanov
Wharton and NBER

July 6, 2011

Abstract

Mortgage refinancing waves tend to coincide with economic downturns. We investigate the role of mortgage refinancing as a mechanism for smoothing consumption by liquidity constrained households, focusing on the interaction of the aggregate economic conditions, interest rates, and idiosyncratic labor income risk. Using both aggregate and state-level data we show that refinancing activity increases when economic conditions deteriorate, even controlling for the cyclical behavior of interest rates, with a larger fraction of loans involving cash-out (equity extraction) around recessions. Calibrating a quantitative model of household decision making that features optimal mortgage choice we show that counter-cyclical labor income risk is important for generating the cyclical behavior of refinancing. At the same time, persistent idiosyncratic shocks that are harder to smooth mitigate this effect, while precautionary saving drives down optimal mortgage balances. Consequently, the observed patterns of mortgage refinancing contain important information about the dynamics of household-level idiosyncratic labor income.

*Please do not cite without permission. We gratefully acknowledge comments and suggestions by Andy Abel, Erik Hurst, Urban Jermann, Greg Kaplan, Nick Souleles, Amir Yaron, and seminar participants at the Philadelphia Fed, USC and Wharton.

1 Introduction

Long-term mortgages with a fixed rate and an option to prepay the outstanding balance prior to maturity, typically by obtaining a new loan (refinancing), have long been the mainstay of the U.S. housing market. This paper investigates the role of mortgage refinancing as a mechanism through which households can relax liquidity constraints in response to aggregate and idiosyncratic shocks by borrowing against their home equity. Fluctuations in interest rates that determine the strength of the financial incentive to refinance alone are not sufficient to capture all of the movement in the aggregate prepayment/refinancing activity in the data (e.g., Boudoukh, Richardson, Stanton, and Whitelaw (1997)). We focus on the interaction between the interest rate variation and macroeconomic conditions in affecting household decisions. The decision to refinance a mortgage either to take advantage of the lower interest rates or to take out home equity for consumption-smoothing purposes trades off the benefits of refinancing against the costs of originating a new loan, both financial and non-pecuniary. The interaction of the two motives for refinancing that underscores its potential importance for the effectiveness of monetary policy.¹

Empirically, interest rates are pro-cyclical, falling in economic downturns, when both aggregate income falls and its cross-sectional dispersion rises. Consequently, the option to prepay an existing fixed-rate mortgage (FRM) is more likely to be in the money at a time when households are constrained and experiencing a need to tap their home equity (if it exists), in effect providing a form of insurance. Indeed, we show that in the data, mortgage

¹Mortgage refinancing featured prominently in Alan Greenspan's defense of low interest rates as a way of stimulating household consumption during the "jobless recovery" from the 2001 recession: "Overall, the economy has made impressive gains in output and real incomes; however, progress in creating jobs has been limited. ... The very low level of interest rates ... encouraged household spending through a variety of channels. ... The lowest home mortgage rates in decades were a major contributor ... engendering a large extraction of cash from home equity. A significant part of that cash supported personal consumption expenditures and home improvement. In addition, many households took out cash in the process of refinancing, often using the proceeds to substitute for higher-cost consumer debt. That refinancing also permitted some households to lower the monthly carrying costs for their homes and thus freed up funds for other expenditures." (Testimony of Chairman Alan Greenspan; Federal Reserve Board's semiannual Monetary Policy Report to the Congress Before the Committee on Financial Services, U.S. House of Representatives, February 11, 2004).

refinancing activity appears to respond to macroeconomic conditions, even after controlling for the cyclicalities of mortgage rates, using both aggregate and state-level data. Refinancing activity spikes with measures of macroeconomic uncertainty such as the implied stock market volatility and unemployment claims, and is lower in states that experience higher rates of economic growth. Refinancing is positively related to growth in house prices, which drives the tightness of the collateral constraint, while more refinancing households extract home equity (“cash-out”) as the economy enters into recessions, even before interest rates fall.

In order to provide an analytical framework for understanding these facts we build a dynamic model of household mortgage financing that replicates these stylized facts. The model also helps quantify the degree to which refinancing costs as well as the lack of home equity constrain the ability of households to smooth consumption in the face of macroeconomic uncertainty.

In our model, households are facing uninsurable idiosyncratic and aggregate labor income risk, and their only means of borrowing is via a home mortgage. The mortgage repayment and refinancing behavior is driven by both the purely financial motive of minimizing the borrowing costs (as in Campbell and Cocco (2003)) and by the consumption-smoothing motive of using home equity to alleviate the liquidity constraint (as in Hurst and Stafford (2004)). An important feature of our model is the counter-cyclical volatility of idiosyncratic labor income growth, documented by Storesletten, Telmer, and Yaron (2004). This property of the labor income process combined with the pro-cyclical interest rates implies that a macroeconomic downturn should coincide with a spike in refinancing activity both due a decline in mortgage rates and because more households become liquidity constrained, provided that the cost of refinancing is low enough and households still have enough home equity.

In a quantitative calibration of the model that targets the main features of income, consumption, and mortgage data we show that the dynamics of labor income are key for generating counter-cyclical refinancing and cash-out behavior. On the one hand, counter-cyclical idiosyncratic labor income risk is important for cyclical behavior of refinancing. On

the other hand, riskier idiosyncratic income implied greater precautionary saving, i.e. greater liquid asset holdings and lower mortgage balances on average. Further, highly persistent labor income processes advocated in the recent literature imply that idiosyncratic shocks are very difficult to smooth, and therefore dampen the effect of economic cycles on refinancing behavior. Thus observed refinancing behavior contains useful information for understanding the dynamics of individual labor income.

A better understanding of the links between mortgage refinancing and macroeconomic conditions is important for several reasons. First, while previous models have predominantly focused on refinancing as exercise of an interest rate option, our results show that the liquidity-driven motive can significantly amplify the demand for refinancing under certain macroeconomic conditions. This is important for pricing prepayment risk in mortgage-related assets (e.g., Duarte, Longstaff, and Yu (2007) show that agency-backed mortgage backed securities are subject to macroeconomic risk captured by stock returns), as well as for understanding the relation between refinancing activity in the mortgage markets and volatility in other fixed income markets (see, e.g., Duarte (2008)). Second, our model can quantify the welfare implications of refinancing costs in a rather rich economic setting, which can help evaluate policy proposals of stimulating the economy through relaxing refinancing constraints.

1.1 Literature

There is a large literature on mortgage refinancing decision, with different strands focusing on different facets of the optimal solution to the problem faced by the household.

The fixed-income asset pricing literature focuses on the optimal exercise of the call option embedded in the mortgage (e.g. Dunn and McConnell (1981), Dunn and Spatt (2005)). The wide divergence of prepayment behavior across households has been modeled by attributing it to implicit heterogeneity in the costs of refinancing (e.g. Stanton (1995), Deng, Quigley, and Van Order (2000), Downing, Stanton, and Wallace (2005)), both explicit and implicit, in

particular those arising from behavioral biases (e.g. Agarwal, Driscoll, and Laibson (2002)). Campbell and Cocco (2003) and Koijen, Van Hemert, and Van Nieuwerburgh (2009) analyze the choice between adjustable and fixed-rate mortgages.

The literature on housing collateral emphasizes the implicit risk-sharing role of mortgage finance and its impact on risk premia (e.g. Lustig and Van Nieuwerburgh (2005), Favilukis, Ludvigson, and Van Nieuwerburgh (2011)). Some evidence supporting the importance of housing collateral has been documented using variation in consumption responses to income at the regional level (Caplin, Freeman, and Tracy (1997), Lustig and Van Nieuwerburgh (2010)). Hurst and Stafford (2004) explicitly consider the role of mortgage refinancing as a mechanism of accessing home equity for the purpose of smoothing consumption over time and provide household-level evidence.

2 Empirical evidence

2.1 Aggregate data

In this section, we discuss empirical evidence on how refinancing activity at the aggregate level relates to interest rates and macroeconomic conditions. The key variable capturing mortgage refinancing by households that we use is the index of mortgage applications compiled by the Mortgage Bankers Association (MBA Refi Index), which is available from 1990 to 2011. In addition, we also examine the quarterly cash-out data from Freddie Mac for the period from 1985 to 2011.

Figure 1 Panel A plots the Refi index (weekly) along with the 30-year mortgage rates. Not surprisingly, refinancing increased in both the early 90s and especially around 2003, both of which are times when mortgage rates came down significantly. This is consistent with households refinancing to take advantage of newly available low mortgage rates. Panel B plots the Refi index with the VIX index, a measure of the implied volatility of the *S&P* 500 stock market index. The spikes in Refi in 1998, 2001, 2008, and 2009 all appear to coincide

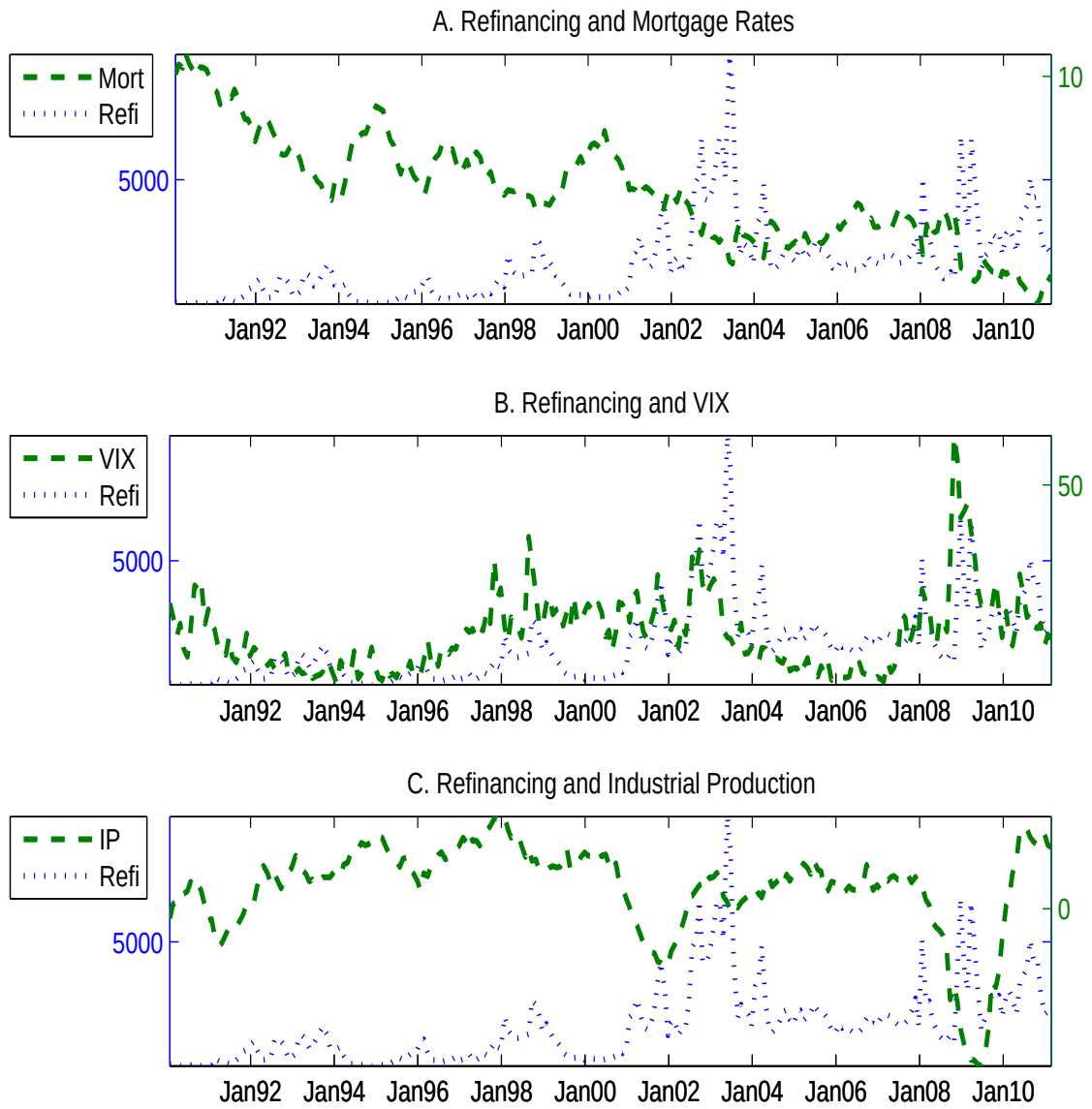


Figure 1: Refinancing, Interest Rates, and Macroeconomic Uncertainty

with spikes in the VIX. Panel C plots the Refi index with the year-on-year growth rate in industrial production. The Refi index rose significantly during the 2001 recession, and again in early 2008, the onset of the Great Recession. Panels B and C are suggestive evidence that households borrow against home equity (while they are not yet “under water”) when experiencing bad income shocks or in anticipation of worsening economic conditions in the future.

We regress the (monthly average) Refi Index on a host of financial and macroeconomic variables:

$$REFI_t = b_0 + b_r R_t^{3M} + b_{r30} R_t^{30Y} + b_{r30l} R_{t-12}^{30Y} + b_{VIX} VIX_t + b_{IP} \Delta IP_t + \epsilon_t, \quad (1)$$

where R_t^{3M} is the 3-month Treasury Bill rate, R_t^{30Y} the 30-year fixed mortgage rate, R_{t-12}^{30Y} the 30-year fixed mortgage rate lagged by one year, and ΔIP_t the year-on-year change in the Industrial Production index (IP).

Table 1 reports the results. The most important driver of mortgage refinancing is the 30-year mortgage rate, which comes in with a negative and robustly significant coefficient in all of the regressions. This is natural, as one of the primary reasons to refinance a mortgage is to take advantage of lower interest rates and thus lower interest payments. The other right-hand side variables are meant to capture the sensitivity of refinancing to the economic conditions: the short rate, which is typically pro-cyclical also comes in with a negative coefficient, as does the Industrial Production growth, which is the most direct measure of economic activity. However, the short rate appears to drive out IP as an explanatory variable. This could indicate that either the interest rate contains more relevant information about the state of the economy, or that it is in fact driving refinancing since it captures the attractiveness short-duration borrowing options, such as adjustable rate mortgages (ARMs). Finally, VIX is significantly positively related to Refi. It also drives out IP, possibly for the reason that financial data are forward-looking and better capture the information set of the

Table 1: Explaining the MBA Refinancing Index - monthly

	R_t^{30Y}	R_t^{3M}	R_{t-12}^{30Y}	VIX	IP	Adj. R^2
1	-8.22 (1.30)					0.52
2	-5.48 (1.03)	-2.20 (0.86)				0.54
3	-7.84 (1.22)				-0.55 (0.24)	0.54
4	-5.87 (0.90)	-1.69 (1.05)			-0.36 (0.27)	0.55
5	-7.54 (1.09)			0.47 (0.20)	-0.22 (0.33)	0.58
6	-9.23 (2.22)	-1.55 (0.86)	3.01 (1.64)	0.39 (0.15)		0.61

NOTE: Monthly data, January 1990 - February 2011. Numbers in parentheses are Newey-West standard errors with 24 lags.

households, and it survives when short rates and lagged mortgage rates are included.

Next, we run similar regressions as (1) using weekly data, where the measures of aggregate economic conditions are VIX and the Initial Claims Unemployment series available from the Federal Reserve Bank of Philadelphia (UIC). The results are similar to those obtained at the monthly frequency. While the 30-year mortgage rate is still the strongest determinant of refinancing, the short-term interest rate and the Initial Claims unemployment index have a negative and a positive sign, respectively, both significant when the other regressor is not present, but neither significant in a joint regression. Both of the variables weaken in the presence of the lagged mortgage rate, consistent with the fact that the level of interest rates changes in the response to changing economic conditions, affecting the attractiveness of refinancing. Again, the stock market volatility index VIX is always strongly significant, driving out all of the other variables except for the key mortgage rate.

Table 2: Explaining the MBA Refinancing Index - weekly

	R_t^{30Y}	R_t^{3M}	R_{t-52}^{30Y}	VIX	UIC	$Adj. R^2$
1	-9.49 (1.41)					0.53
2	-6.60 (1.00)	-2.36 (0.92)				0.56
3	-8.63 (1.18)				0.45 (0.17)	0.56
4	-7.33 (0.94)	-1.28 (1.15)			0.31 (0.19)	0.57
5	-8.13 (1.08)			0.46 (0.18)	0.25 (0.20)	0.61
6	-9.50 (2.13)	-1.40 (0.87)	3.08 (1.60)	0.45 (0.14)		0.63

NOTE: Weekly data, from January 1990 - March 2011. Numbers in parentheses are Newey-West standard errors with 52 lags.

2.2 State level evidence

To investigate the response of mortgage refinancing to economic activity further, we use state-level data on the origination of home mortgage loans at the state level. This potentially allows us to separate the effect of low interest rates from that of deteriorating economic conditions, insofar as there is heterogeneity in business conditions across states so that local economic activity variables are less synchronized with the interest rates than are aggregate quantities, and that households cannot diversify away state-level shocks.

We first use quarterly data on the mortgage loans (both refinance and purchase) for each of the 50 states and DC, normalized by the state population based on aggregated Home Mortgage Disclosure Act (HMDA) reporting. We regress the quarterly changes in the number of loans taken in order to refinance existing mortgages (adjusted by the state population) on measures of economic conditions. We use two such measures: growth rates of nonfarm payroll employment and of the State Coincident Economic Activity Index (*CEAI*), which combines information contained in nonfarm payrolls, unemployment, hours worked

and wages, and trends with the Gross State Product (GSP).² We use year-on-year (log) growth rates at the quarterly levels of these measures as the main explanatory variables.

House prices determine both the motive to refinance due to a wealth effect and the ability of households to borrow against the value of their homes (perhaps for reasons unrelated to consumption smoothing). Since economic conditions are correlated with the level of house prices, refinancing activity could be high under good economic conditions due to high house prices. Thus, to better capture the effect of consumption smoothing on refinancing, it is important to control for house price appreciation in our regression. We use the FHFA house price indices for the 50 states and DC as our measure of house prices. As before, we also control for several aggregate variables: the 30 year mortgage rate, the short-term interest rate, and the VIX volatility index.

We run pooled time series/cross-sectional regressions of the form:

$$\begin{aligned} REFI_t^{State} = & b_{Cycle} Cycle_t^{State} + b_{CycleLag} Cycle_{t-4}^{State} + b_{HPI} \Delta HPI_t^{State} + b_{CH} Cycle_t^{State} \times HPI_t^{State} \\ & + b_w WAC_t^{State} + b_r R_t + b_{r30} R_t^{M30} + b_{r30l} R_{t-12}^{M30} + b_{vix} VIX_t + \mathbf{b}_t + \mathbf{b}_{State} + \epsilon_t, \end{aligned} \quad (2)$$

where $Cycle^{State}$ is the variable that measures state-level aggregate economic conditions, ΔHPI_t measures house price appreciation using the 1-year growth in the FHFA state-level house price index, WAC_t^{State} is the weighted average coupon on conforming mortgage loans outstanding in the state in the first month of the quarter, $\mathbf{b}_t$ is the vector of quarter fixed effects, and $\mathbf{b}_{State}$ a vector of state fixed effects. State fixed effects are important since there is substantial heterogeneity across states in the fixed costs associated with refinancing a mortgage (such as title insurance, taxes, etc.), which result in different average levels of refinancing as well as its sensitivity to aggregate variables. Given this specification, we are identifying the effect of within-state variation in economic conditions on refinancing. We include the lagged $Cycle$ variable to capture delayed response of households to economic

²Unlike the payroll growth measure, this variable is not available for DC.

conditions, and include an interaction term between *Cycle* and the house price growth, orthogonalized with respect to both variables, to test whether higher level of house prices help relax the borrowing constraint especially in bad times.

Table 3 presents the results of the state-level regressions for different specifications (two different economic activity measures). The coefficients on the state-level business cycle variables in the first column are all negative and statistically significant in all but one specification (CEAI without time fixed effects), consistent with the view that households are more likely to refinance their mortgages in a downturn. The one-year lagged *Cycle* variables are even more strongly negative and always statistically significant, suggesting that local economic conditions are persistent. The lagged variables may have a stronger effect than the contemporaneous ones because more prolonged regional recessions are likely to exert greater pressure on the financial resources of households, driving them to rely more on housing collateral to smooth the temporary but persistent fluctuations. The state-level cycle variable remains significantly negatively related to refinancing when the quarter fixed effects are included, indicating that their presence does not simply proxy for variation in the aggregate term structure variables.

As expected, house price appreciation is positively related to refinancing. The effects of the business cycle variables become stronger (more negative) after house price appreciation is taken into account, which helps tease out the rise in refinancing in good times due to house value appreciation. Moreover, the interaction terms of house prices and the cycle variables are negative and typically statistically significant, suggesting that higher levels of house prices are particularly important for refinancing during economic downturns.

Both the 30-year mortgage rates and the short-term interest rate have a significant negative effect on refinancing, as expected. Similarly, the WAC has a significant positive coefficient, consistent with the fact that it captures the rates currently paid by borrowers, so that higher WAC translated into a greater incentive to refinance if current rates are low. In the specification with time fixed effects (where aggregate interest rates are not included)

WAC has a negative coefficient, potentially due to the fact that it may capture persistent state-specific variation in mortgage spreads that we cannot control for separately without detailed state-level data on mortgage rates.

Table 3: State-level refinancing activity

	$Cycle_t$	$Cycle_{t-4}$	HPI_t	$Cycle_t \times HPI_t$	WAC	R_t^{M30}	R_t	R_{t-4}^{M30}	R^2
1	-0.12	-0.42	0.22	-0.04	0.27	-5.58	-0.82	4.75	0.65
<i>Robust</i>	[0.04]	[0.06]	[0.01]	[0.01]	[0.03]	[0.30]	[0.05]	[0.32]	
<i>NW</i>	[0.05]	[0.06]	[0.01]	[0.00]	[0.05]	[0.26]	[0.05]	[0.25]	
2	-0.18	-0.13	0.17	-0.02	-4.11				0.88
<i>Robust</i>	[0.05]	[0.04]	[0.02]	[0.01]	[0.77]				
<i>NW</i>	[0.05]	[0.04]	[0.02]	[0.00]	[0.69]				
3	-0.00	-0.31	0.21	-0.03	0.32	-5.82	-0.84	4.85	0.65
<i>Robust</i>	[0.02]	[0.03]	[0.01]	[0.01]	[0.03]	[0.33]	[0.05]	[0.33]	
<i>NW</i>	[0.03]	[0.04]	[0.01]	[0.00]	[0.05]	[0.26]	[0.05]	[0.26]	
4	-0.09	-0.11	0.17	-0.01	-3.95				0.88
<i>Robust</i>	[0.04]	[0.03]	[0.02]	[0.00]	[0.77]				
<i>NW</i>	[0.04]	[0.03]	[0.02]	[0.00]	[0.72]				

Quarterly data, 1993.III - 2009.IV. *Cycle* refers to the year-on-year growth in either the non-farm payroll employment index scaled by the state population (*Payroll*, specifications 1 - 2) or the State Coincident Economic Activity index in columns (*CEAI*, specifications 3 - 4). *HPI* is the annual growth rate of the state-level house price index, *WAC* is weighted average coupon rate for conforming fixed-rate mortgages (equal-weighted average across FNMA and FHLMC loans) in a given state. Specifications 2 and 4 have quarter fixed effects. Standard errors are in brackets (*Robust* are clustered by state, and *NW* are Newey-West with 20 lags).

If households use refinancing in order to take advantage of housing collateral to smooth consumption in downturns, we should expect the size of new refinance loans to increase relative to household income during periods of low economic growth. Table 4 present the results of a regression for the changes in the state-level average loan-to-income ratios (LTI):

$$\begin{aligned}
\Delta LTI_t^{State} = & b_{Cycle} Cycle_t^{State} + b_{HPI} \Delta HPI_t^{State} + b_{CH} Cycle_t^{State} \times HPI_t^{State} \\
& + b_w WAC_t^{State} + b_r R_t + b_{r30} R_t^{M30} + b_{r30l} R_{t-12}^{M30} + b_{vix} VIX_t + \mathbf{b}_t + \mathbf{b}_{State} + \epsilon_t,
\end{aligned}
\tag{3}$$

where ΔLTI is the year-on-year change in the logarithm of the average loan-to-income ratio by state. We use first differences rather than levels of LTI due to the fact that the LTI levels appear to trend upwards over our sample, perhaps due to the effects of financial innovation and regulation on the availability of mortgage loans to low income households, in particular via subprime mortgages. The results reported in the table indicate that the average loan-to-income ratios on refinance loans do tend to increase when macroeconomic conditions (especially as captured by payroll employment) deteriorate. Not surprisingly, LTI is positively related to house prices, but there is virtually no interaction between the two effects. LTI is negatively related to current interest rates, suggesting that larger mortgages become more affordable to households in low interest rate environments, and the positive relation to WAC and lagged mortgage rates suggest that households increase their mortgage balances upon refinancing especially if the current coupon rates they pay on existing loans are high. Overall, this evidence, albeit only suggestive, is consistent with the view that households use refinancing to access home equity during economic downturns.

2.3 Cash-out evidence

Measures of aggregate and state refinancing activities do not distinguish between cash-out refinances (taking out a loan with a larger balance than the previous one) from those that result in the same or lower loan balances. We now examine how cash-outs react to macroeconomic conditions, which provide a more direct measure of household borrowing.

Figure 2 Panel A plots the time series of the percentage of refinances for which the loan amount (i) is raised by 5% or more, (ii) remains the same, or (iii) is reduced by 5% or more. The data is from Freddie Mac for the period of Q1 of 1985 to Q1 of 2011. On average, 61% of refinances over this period are cash-outs, which highlights the importance of cash-outs in mortgage refinancing. The share of cash-outs is visibly higher towards the end of each expansion, and it becomes lower after a recession. In contrast, the fraction of refinances that do not result in a higher loan balance does not appear to have a clear business

Table 4: Average loan-to-income ratios

	$Cycle_t$	HPI_t	$Cycle_t \times HPI_t$	WAC	R_t^{M30}	R_t	R_{t-4}^{M30}	R^2
1	-0.26	0.35	-0.01	1.17	-7.46	-1.46	6.53	0.10
<i>Robust</i>	[0.23]	[0.05]	[0.03]	[0.33]	[2.04]	[0.22]	[1.20]	
<i>NW</i>	[0.21]	[0.05]	[0.02]	[0.37]	[1.84]	[0.21]	[1.30]	
2	-0.48	0.48	0.01	13.30				0.25
<i>Robust</i>	[0.17]	[0.09]	[0.02]	[8.23]				
<i>NW</i>	[0.17]	[0.09]	[0.02]	[7.40]				
3	-0.03	0.30	0.00	1.25	-7.99	-1.60	6.83	0.10
<i>Robust</i>	[0.12]	[0.06]	[0.01]	[0.37]	[2.25]	[0.18]	[1.29]	
<i>NW</i>	[0.12]	[0.06]	[0.01]	[0.40]	[2.02]	[0.19]	[1.38]	
4	0.00	0.40	0.01	12.61				0.25
<i>Robust</i>	[0.20]	[0.12]	[0.01]	[8.08]				
<i>NW</i>	[0.18]	[0.11]	[0.01]	[7.34]				

NOTE: Quarterly data, 1993.III - 2009.IV (time subscript t is in monthly units). Year-on-year log growth in average loan to income ratio (for refinance loans only) at the state level, in percentage points (based on HMDA data). *Cycle* refers to the year-on-year growth in either the non-farm payroll employment index scaled by the state population (*Payroll*, specifications 1 - 2) or the State Coincident Economic Activity index in columns (*CEAI*, specifications 3 - 4). *HPI* is the annual growth rate of the state-level house price index, *WAC* is weighted average coupon rate for conforming fixed-rate mortgages (equal-weighted average across FNMA and FHLMC loans) in a given state. Specifications 2 and 4 have quarter fixed effects. Standard errors are in brackets (*Robust* are clustered by state, and *NW* are Newey-West with 20 lags).

cycle pattern. The waves in the mid-90s and early 2000s instead correspond to periods of declines in mortgage rates, which is intuitive since the goal of such refinances should be to reduce interest payments. Finally, the fraction of pay-down refinances, those that result in a reduction in loan balance, typically rises following a recession, as households repay the loans they take out entering the recession. These pay-downs should also be associated with lower rates, for otherwise households could prepay rather than refinance their mortgages.

Like other types of refinancing, cash-outs can also be due to low interest rates. Thus, it is informative to examine under what conditions refinancing tends to lower loan rates Panel B of Figure 2 plots the ratio of the median new mortgage rates on refinance loans to the old mortgage coupon rates k . Households tend to refinance despite higher rates towards the

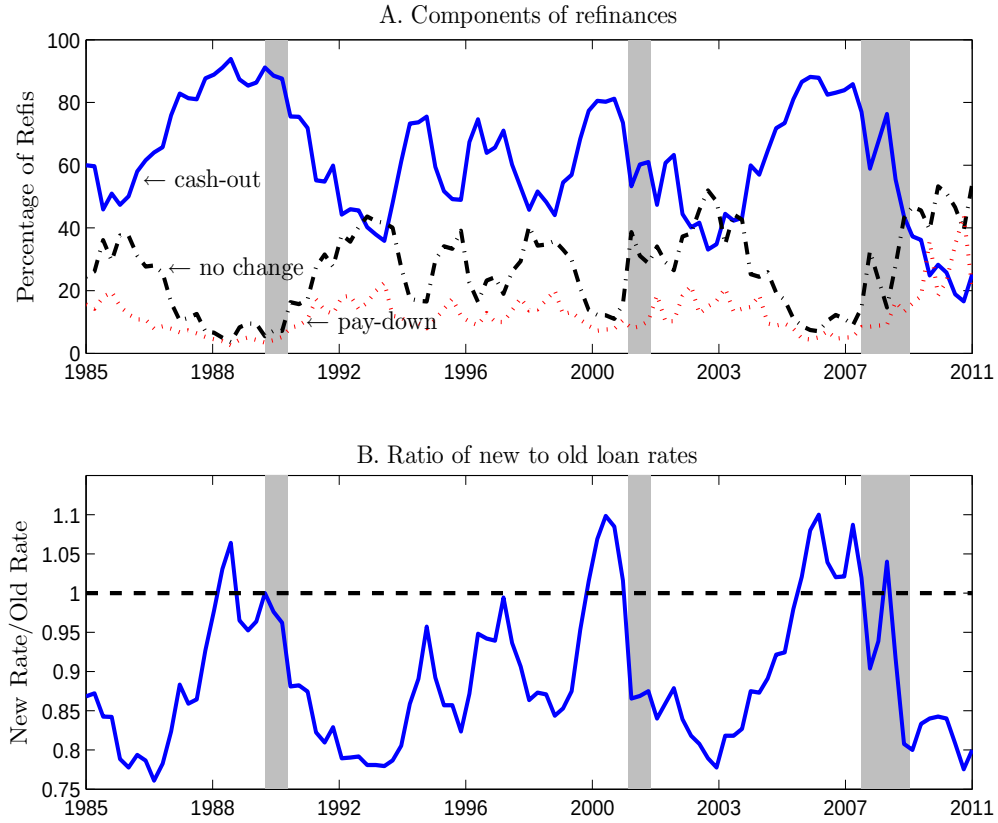


Figure 2: Panel A plots the percentage of refinances resulting in 5% higher loan amount (cash-out), no change in loan amount, or lower loan amount (pay-down). Panel B plots the median ratio of new to old loan rates upon refinance.

end of economic expansions, but at lower rates coming out of recessions. The correlation between this rate ratio and the cash-out share in Panel A is 78%. Together, they suggest that macroeconomic factors other than interest rates play an important role in determining the aggregate amount of cash-out refinancing.

Why do households refinance their mortgages at higher rates? One possibility is that they are borrowing against higher expected future income. Given that labor income is not tradable and other non-collateralized personal loans (e.g., credit card loans) are expensive, the house becomes a source of credit for liquidity constrained households. A second, and related, reason is that households borrow when they are experiencing or anticipating a temporary

drop in income (consumption smoothing). Frictions such as loan-to-income ratio restriction, and more severe adverse selection due to higher income volatility in the cross section can make it more difficult (costly) to borrow in bad times, which will generate precautionary demand for borrowing before income has fallen. Third, households might expect long term mortgage rates to rise in the future, so they may be attempting to “time the market” by taking out larger mortgages in anticipation and locking in the low rate. Fourth, households might expect house value to fall, which affects their future borrowing capacity through the loan-to-value ratio restriction.³ Finally, if households expect higher returns from other types of investment (e.g., from the stock market), they might borrow against the house in spite of high rates.

We explore some of these alternative explanations in Table 5. The ratio of new to old loan rates predicts future GDP growth with a significantly negative coefficient and an R^2 of 22%, which is consistent with the precautionary demand for cash-out due to liquidity constraint. This effect survives after controlling for short rate, term spread, and the median appreciation of refinanced property. High rate ratio predicts lower future long term mortgage rates, suggesting that cash-out at the onset of recession is not for the purpose of locking in the rate. It also predicts lower short rates and lower house price growth. It is possible that households refinance into adjustable rate mortgages (ARMs) when they expect short rates to fall, although the share of ARMs in total new loans is typically low when the rate ratio is high. Finally, high rate ratios predicts lower excess returns for stocks one year ahead, making it a poor strategy to cash out and invest in the stock markets when the rate ratio is high. We cannot rule out that households irrationally believe that future market returns will be high. Overall, however, the time-series behavior of cash-out and the rate ratio are consistent with households taking out loans to smooth consumption as they entering into a recession and their financial position deteriorates.

³Higher expected house price might also lead to more cash-out if the households are willing to move down to cheaper (and lower quality) houses, or if they own investment properties.

Table 5: Predicting Macro Variables with Refinancing Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		GDP_{t+4}		R_{t+4}^{M30}	R_{t+4}	HPI_{t+4}	ER_{t+4}^m
k^{new}/k^{old}	-0.097 (0.032)	-0.151 (0.036)	-0.116 (0.041)	-2.302 (1.559)	-7.171 (2.811)	-0.093 (0.047)	-0.626 (0.336)
R_t		0.002 (0.001)	0.004 (0.002)		0.908 (0.116)		
$R_t^{10Y} - R_t$		-0.004 (0.003)	-0.003 (0.003)				
ΔH			-0.039 (0.029)				
R_t^{M30}				0.828 (0.078)			
HPI_t						0.836 (0.119)	
$Adj. R^2$	0.218	0.320	0.353	0.800	0.686	0.647	0.092

NOTE: Quarterly data, Q1 1985 - Q1 2011. The left-hand-side variables are one-year ahead annual real GDP growth rate (GDP), one-year ahead 30-year mortgage rate (R^{M30}), one-year ahead 3-month treasury bill rate (R), one-year ahead annual growth rate in house price (HPI), and one-year ahead market excess return (ER^m). Numbers in parentheses are Hansen-Hodrick standard errors with 4 lags. k^{new}/k^{old} is the median ratio of new to old loan rates. ΔH is the median appreciation of the refinanced property.

3 Quantitative Model

This section presents a dynamic model of household decisions. This model will focus on understanding households' decisions on how much to consume, save and finance a house over time, as a function of idiosyncratic shocks to income and aggregate shocks to short-term interest rates, real growth, house value, and inflation.

3.1 Environment

The economy is populated by ex-ante identical households. Each household is denoted by the index i . Each household is endowed with a house with time-varying market price H_t , and one unit of labor supplied inelastically that receives an after-tax wage $(1 - \tau)y_{it}$. The

idiosyncratic income process is stochastic and will be key in the optimal behavior.

Households can save using a one-period liquid asset a_{it} that pays the aggregate short rate in the economy, denoted by r_t^s . The households are also prevented from borrowing, that is $a_{it} \geq 0$ for all t . All variables are nominal –expressed in units of account, say \$– and the price level at time t is denoted by p_t . The model will thus feature inflation risk.

3.2 Mortgages

For simplicity, mortgages in this economy are assumed to be interest-only mortgages. Households have to meet a mortgage payment every period, defined as the (fixed) mortgage coupon rate k_i times the mortgage balance due on the house b_{it} . Note that the households can deduct the mortgage interest expense, which is the full mortgage payment for an interest-only mortgage, from their taxable income y_{it} .

Households can always repay their mortgage by reducing the outstanding loan balance on their home, that is when $b_{i,t+1} < b_{it}$. The repayment decision is denoted by the indicator $I_{it}^{RP} = 1$ if home loan balance is reduced and $I_{it}^{RP} = 0$ otherwise.

Households also have the option to refinance their home by increasing or reducing the outstanding loan balance, that is when $b_{i,t+1} \neq b_{it}$. The refinancing decision is denoted by the indicator $I_{it}^{RF} = 1$ if the home loan is refinanced and $I_{it}^{RF} = 0$ otherwise. When households decide to refinance, they will incur a cost captured by the function ϕ . For example, if a household “pulls out” an amount $(b_{i,t+1} - b_{it})$ from their home equity, they will incur a refinancing cost equal to $\phi(b_{i,t+1})$. Therefore the net proceeds from refinancing will in fact be equal to $b_{i,t+1} - b_{it} - \phi(b_{i,t+1})$, which is the loan increase/decrease net of refinancing cost. These refinancing costs can be thought of the time cost spent on the refinancing process as well as direct finance fees associated with issuing a new mortgage. In this paper, we assume that refinancing costs have a fixed and proportional component.

When a household refinances, the old outstanding mortgage b_{it} is repaid in full using the proceeds of the new mortgage and the available assets. The new home loan is $b_{i,t+1}$ and

the new mortgage rate $k_{i,t+1}$ that is used to calculate future annuity payments is equal to the available refinancing rate R_t . Therefore by refinancing a household commits to repay an infinite stream of constant annuity payments equal to $R_t b_{i,t+1}$, unless the house is refinanced again in the future. The dynamics of the mortgage rate k_{it} will be as follows,

$$k_{i,t+1} = k_{it} (1 - I_{it}^{RF}) + R_t I_{it}^{RF}.$$

Finally households can choose to merely pay their mortgage and neither refinance nor repay their home loan. This decision is denoted by the indicator $I_{it}^{NR} = 1$ if home loan and the mortgage rate are unchanged, and $I_{it}^{NR} = 0$ otherwise.

To start the economy, we assume that each household is endowed with a mortgage balance of b_{i0} , a mortgage rate equal to k_{i0} , and a house of value H_t . In other words, each household is endowed with home equity equal to $H_0 - b_{i0}$, and has to pay a mortgage annuity payment equal to $k_{i0} b_{i0}$. Households are allowed to borrow less than the full value of their home, that is they face the following constraint upon refinancing,

$$b_{i,t+1} \leq \xi H_t,$$

where $\xi \in [0, 1]$ is the parameter that controls the tightness of the *loan-to-value constraint*.

3.3 Household Budget Constraint

Each household will choose how much to consume, save in a riskless one-period bond that pays the short rate r , and adjust their mortgage: both the rate and the outstanding loan amount. The budget constraint for household i at time t is given by,

$$c_{it} + \frac{a_{i,t+1}}{1 + (1 - \tau)r_t^{\$}} + b_{it} = (1 - \tau)(y_{it} - k_{it}b_{it}) + a_{it} + b_{i,t+1} - \phi(b_{i,t+1})I_{it}^{RF}.$$

Notice that interests earned on the liquid asset a are taxed at the same rate τ as wage

income.

3.4 Exogenous States

3.4.1 Aggregate States

The real macroeconomic risk in the economy is summarized by the aggregate state variable Z_t . This process gives the real growth rate of the aggregate real income: $Z_{t+1} = Y_{t+1}/Y_t$. The nominal short rate $r_t^\$$ is also an aggregate state variable.

Because all variables in the model are nominal but consumers derive utility from real consumption, we need to specify a process for inflation. Recall that the price level at time t is denoted by p_t , thus the (gross) inflation rate is defined as $\pi_{t+1} = p_{t+1}/p_t$.

We make the assumption that nominal house prices H_t have a component that grows at the same rate as the economy (i.e. nominal aggregate income), as well as a component that represents the aggregate risk inherent in the housing market's transitory deviations from the trend in aggregate income. Therefore, the house price process is given by,

$$H_t = p_t Y_t \bar{H} \tilde{h}_t, \quad (4)$$

where $\bar{H}$ is the house price level (in terms of the consumption good), and the shocks $\tilde{h}_t$ are assumed to be stationary, so that real house price level is cointegrated with real aggregate income.

These four aggregate state variables are summarized in the aggregate state vector $S_t \equiv (r_t^\$, Z_t, H_t, \pi_t)$ that follows a first-order vector autoregressive process (VAR) in logarithms.

3.4.2 Idiosyncratic States

The nominal income process y_{it} for each household has an aggregate component, Y_t , as well as an idiosyncratic component, $\tilde{y}_{it}$, and is given by,

$$y_{it} = p_t Y_t \tilde{y}_{it}, \quad (5)$$

where the idiosyncratic shocks $\tilde{y}_{it}$ follow an autoregressive process with state-dependent conditional volatility, i.e. heteroscedastic innovations, given by,

$$\log \tilde{y}_{it} = \log \mu_y(Z_t) + \rho_y \log \tilde{y}_{i,t-1} + \sigma(Z_t) \epsilon_{it}^y, \quad \epsilon_{it}^y \sim \mathcal{N}(0, 1). \quad (6)$$

The counter-cyclical nature of the idiosyncratic labor income risk is emphasized by Storesletten, Telmer, and Yaron (2004). We calibrate $\mu_y(Z_t)$ so that the cross-sectional mean of the idiosyncratic components of income $\tilde{y}$ implied by the stationary distribution equals to unity in every period:

$$\log \mu_y(Z) = -\frac{1}{2} \frac{\sigma^2(Z)}{1 + \rho_y}$$

We assume that all households bear the same aggregate risks since we focus on the “average” households that is likely to need to use home equity to smooth consumption (there is some evidence in the recent literature that wealthier households are disproportionately affected by aggregate fluctuations - e.g. Parker and Vissing-Jorgensen (2009)).

The vector of exogenous state, denoted by s_{it} , contains the idiosyncratic wage and the aggregate states: $s_{it} \equiv (y_{it}, S_t)$.

3.5 Household Recursive Problem

In order to simplify notation subscripts t are dropped and primes denote next period variables. The problem for household i is to choose consumption c_i , the position in a liquid asset

a'_i , and whether to refinance I_i^{RF} , repay early I_i^{RP} (yielding new mortgage balance b'_i), or default on the mortgage, so as to maximize the expected lifetime utility of real consumption.

Households choose whether to be a home-owner or a renter. As a home-owner, a household can choose to repay the mortgage and remain a home-owner, sell the house at market value or simply default on the mortgage and rent. As a renter, a household can choose to remain a renter or buy house. Figure 3.5 shows a diagram that represents the households' homeownership decisions. This approach broadly follows Campbell and Cocco (2010) in the treatment of the homeownership and default decision.

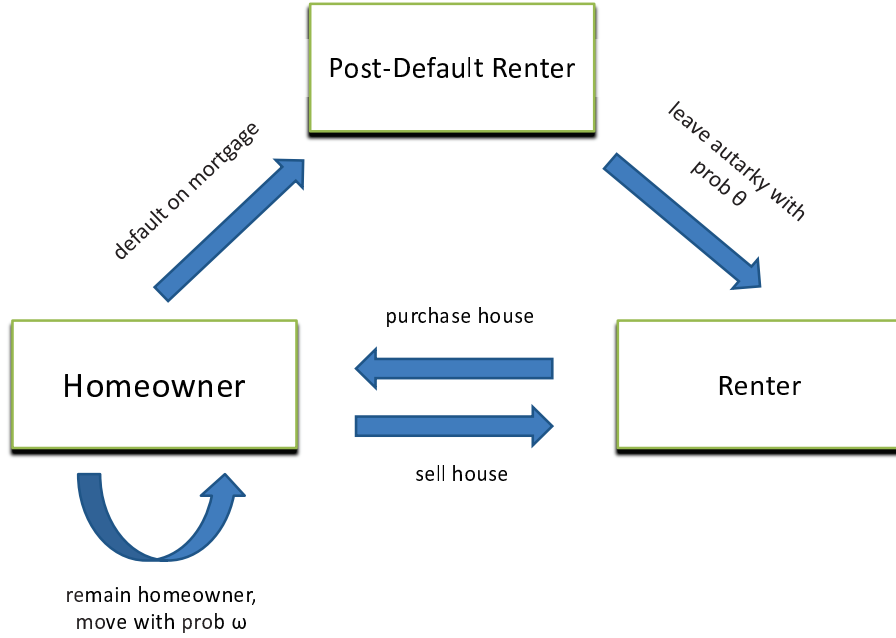


Figure 3: Home-owner, renter, and post-default renter diagram.

3.5.1 Home-owner Problem

As a home-owner, a household chooses consumption and stock of liquid assets, but also has access to borrowing against his house. Every period, there is a probability ω that the household has to move for exogenous reasons (i.e. geographic relocation, buy a different

house, etc.). In such an event, the household has to sell its house, repay the existing loan outstanding, and use the proceeds along with its liquid assets and possibly a new mortgage loan to buy a new house. Equivalently, households are forced to refinance their home at the prevailing rate in the economy with a probability ω each period.

The household problem in the home-owner state can be formalized as follows,

$$U_i^h = \max_{a'_i, b'_i, I_i^{RF}} u(c_i/p) + \beta \mathbb{E} \left[\omega \max \left(U_i^{hh'}, U_i^{hr'}, U_i^{hd'} \right) + (1 - \omega) \max \left(U_i^{h'}, U_i^{hr'}, U_i^{hd'} \right) \right], \quad (7)$$

subject to,

$$\begin{aligned} c_i + \frac{a'_i}{1 + (1 - \tau)r^\$} + b_i &= (1 - \tau)(y_i - k_i b_i) + a_i + b'_i - (pY\phi_0 + \phi_1 b'_i) I_i^{RF}, \\ k'_i &= k_i (1 - I_i^{RF}) + R I_i^{RF}, \\ (b'_i - b_i) (1 - I_i^{RF}) &\leq 0, \\ (b'_i - \xi H) I_i^{RF} &\leq 0, \\ a'_i, c_i, b'_i &\geq 0. \end{aligned}$$

where we denote the value function of the household in the home-owner state by $U_i^h(a_i, b_i, k_i, s_i)$, by $U_i^{hh}(a_i, b_i, k_i, s_i)$ in a state of refinancing the mortgage loan a current rates and remaining a home-owner, by $U_i^{hr}(a_i, b_i, k_i, s_i)$ in a state of transition between being a home-owner and a renter by selling the home, and by $U_i^{hd}(a_i, b_i, k_i, s_i)$ in a state of transition between being a home-owner and a renter by defaulting on the mortgage. These problems will be written down explicitly in what follows.

Note that the cost of refinancing is the sum of a fixed component and a proportional component. However, given that the economy is growing over time, the fixed cost of refinancing is assumed to be scaled with the nominal growth rate in the economy, that is, we

assume the following functional form,

$$\phi(b'_i) = pY\phi_0 + \phi_1 b'_i.$$

The household problem in the home-owner state when forced to move can be formalized as follows,

$$U_i^{hh} = \max_{a'_i, b'_i} u(c_i/p) + \beta \mathbb{E} \left[\omega \max \left(U_i^{hh'}, U_i^{hr'}, U_i^{hd'} \right) + (1 - \omega) \max \left(U_i^{h'}, U_i^{hr'}, U_i^{hd'} \right) \right], \quad (8)$$

subject to,

$$\begin{aligned} c_i + \frac{a'_i}{1 + (1 - \tau)r^s} + b_i &= (1 - \tau)(y_i - k_i b_i) + a_i + b'_i - (pY\phi_0 + \phi_1 b'_i), \\ k'_i &= R, \\ b'_i &\leq \xi H, \\ a'_i, c_i, b'_i &\geq 0. \end{aligned}$$

Home-owners have the option to sell their home at any time. When they do so, they repay the outstanding mortgage –including current mortgage coupon payment– using the proceeds, minus the transaction cost ϕ_2 , and their stock of liquid assets. As a result, they become renters with savings equal to $H(1 - \phi_2) - (1 + (1 - \tau)k)b + a$. The transition problem for the household from the home-owner to the renter state by selling his home is given by,

$$U_i^{hr}(a_i, b_i, k_i, s_i) = \max_{a'_i} u(c_i/p) + \beta \mathbb{E} [U_i^r(a'_i, s'_i)], \quad (9)$$

subject to,

$$\begin{aligned} c_i + \frac{a'_i}{1 + (1 - \tau)r^s} &= (1 - \tau)(y_i - k_i b_i) + a_i + H(1 - \phi_2) - b_i, \\ a'_i, c_i &\geq 0. \end{aligned}$$

Home-owners have the option to default on their mortgage. When a household defaults on its mortgage obligation b , the home is ceased, as well as a portion of its liquid assets, i.e. the household is left with ζa (the parameter ζ could be seen as a way to capture full or partial recourse as well as other costs of default, such as their effect on credit history, in reduced form). As a result, the stock of liquid assets is reduced and the household cannot borrow any more, i.e. $b = 0$ as a renter. Furthermore, the household that defaulted on its mortgage will stay in the rental market for a stochastic period of time, and thus will have random access to the opportunity to regain home-ownership. In other words, households are allowed to regain home-ownership status with probability θ each period, if they find it optimal. The transition problem for the household from the home-owner to the renter state by defaulting on his mortgage is given by,

$$U_i^{hd}(a_i, b_i, k_i, s_i) = \max_{a'_i} u(c_i/p) + \beta \mathbb{E} [U_i^d(a'_i, s'_i)] , \quad (10)$$

subject to,

$$\begin{aligned} c_i + \frac{a'_i}{1 + (1 - \tau)r^\$} &= (1 - \tau)y_i + \zeta a_i, \\ a'_i, c_i &\geq 0. \end{aligned}$$

The value functions U^h , U^{hh} , U^{hr} , and U^{hd} , are conditional on choosing that state. In addition the home-owner household has to choose which of these states is optimal. The unconditional value function for household i in the home-owner state is denoted by $V_i^h(a_i, b_i, k_i, s_i)$ and is defined as the best option from remaining a home-owner, selling or defaulting on its mortgage and becoming a renter. When the household is not moving, with probability $(1 - \omega)$ each period, the value function is defined as,

$$V_i^h = \max (U_i^h, U_i^{hr}, U_i^{hd}) . \quad (11)$$

However, when the household is moving, with probability ω each period, the value function is defined as,

$$V_i^h = \max (U_i^{hh}, U_i^{hr}, U_i^{hd}) . \quad (12)$$

3.5.2 Renter Problem

As a renter, a household must pay rent every period. For tractability, we assume that households will allocate a constant fraction of their consumption toward that rent expense every period.⁴ Thus we assume that rent expense each period is equal to ψc_i . In addition, we assume that households suffer a utility loss of not being home-owners given by $\psi u(c_i/p)$, which is decreasing in the level of rent. This simply states that households will prefer, all else equal, to live in a house they own rather than rent, and that a higher rent will afford a higher quality home, which in turn lower the loss of utility of renting versus owning.

The household problem in the post selling renter state –without being excluded from accessing home-ownership– is given by,

$$U_i^r = \max_{a'_i} (1 + \psi) u(c_i/p) + \beta \mathbb{E} \left[\max (U_i^{rh'}, U_i^{r'}) \right] , \quad (13)$$

subject to,

$$\begin{aligned} (1 + \psi) c_i + \frac{a'_i}{1 + (1 - \tau)r^\$} &= (1 - \tau)y_i + a_i, \\ a'_i, c_i &\geq 0. \end{aligned}$$

When in the post selling renter state, the value function for household i is defined as the best option from remaining a renter or becoming a home-owner, that is,

$$V_i^r = \max (U_i^{rh}, U_i^r) . \quad (14)$$

⁴This assumption can be microfunded by assuming that households choose the level of rent each period as a static choice and that they have a power utility over real rent payment and that it is additive to the utility over real consumption.

The transition problem for the household from the renter to the home-owner state is given by,

$$U_i^{rh}(a_i, s_i) = \max_{a'_i, b'_i} (1 + \psi) u(c_i/p) + \beta \mathbb{E} [U_i^h(a'_i, b'_i, R, s'_i)], \quad (15)$$

subject to,

$$\begin{aligned} (1 + \psi) c_i + \frac{a'_i}{1 + (1 - \tau)r^\$} + H(1 - \phi_2) &= (1 - \tau)y_i + a_i + b'_i - (pY\phi_0 + \phi_1 b'_i), \\ b'_i &\leq \xi H, \\ a'_i, c_i, b'_i &\geq 0. \end{aligned}$$

3.5.3 Post Default Renter Problem

The household problem in the post default renter state is given by,

$$U_i^d = \max_{a'_i} (1 + \psi) u(c_i/p) + \beta \mathbb{E} [(1 - \theta)U_i^{d'} + \theta \max(U_i^{rh'}, U_i^{r'})], \quad (16)$$

subject to,

$$\begin{aligned} (1 + \psi) c_i + \frac{a'_i}{1 + (1 - \tau)r^\$} &= (1 - \tau)y_i + a_i, \\ a'_i, c_i &\geq 0, \end{aligned}$$

where we denote the value function of the household in transition between the renter state and the home-owner state by $U_i^{rh}(a_i, s_i)$.

When in the post default renter state, the unconditional value function for household i is defined as the best option from remaining a renter or becoming a home-owner if the exclusion from home-ownership period ends, i.e. with probability θ each period,

$$V_i^d = \max(U_i^{rh}, U_i^r), \quad (17)$$

or is simply equal to the value function in post default renter state if the home-ownership option is unavailable to him, i.e. $V_i^d = U_i^d$.

3.6 Stationary Reformulation of the Household Recursive Problem

Let the household utility be CRRA, $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$, then we can rescale the problem with respect to the permanent aggregate income Y_t and the price level p_t in order to make it stationary. We can rescale the variables, as well as the state vector such that the rescaled household problems are stationary. The algebraic details are given in the Appendix.

3.7 Household Optimal Policies

The optimal policies for liquid asset holdings, home loan, and mortgage rate are denoted by $a'_i = g_{i,a}(a, b, k, s)$, $b'_i = g_{i,b}(a, b, k, s)$, and $k'_i = g_{i,k}(a, b, k, s)$. In addition, the discrete refinancing policy is denoted by $I_i^{RF} = g_{i,RF}(a, b, k, s)$. The optimal repayment policy denoted by $I_i^{RP} = g_{i,RP}(a, b, k, s)$ can be constructed out of the optimal loan and refinancing policies,

$$I_i^{RP} = \mathbb{I}_{b'_i \neq b_i} (1 - I_i^{RF}).$$

Similarly the optimal no refinancing/repayment policy denoted by $I_i^{NR} = g_{i,NR}(a, b, k, s)$ can be constructed out of the optimal refinancing and repayment policies,

$$I_i^{NR} = 1 - I_i^{RP} - I_i^{RF}.$$

4 Calibration Results

This section describes the implications of the model in Section 3. There is no closed-form solution for this model, therefore we use numerical techniques to approximate it. Specifically,

we discretize the state space and apply standard numerical dynamic programming and then simulate the optimal policies for a large panel of households. We explain the choice of the key parameters of the model and characterize the solution.

4.1 Parameter Choice

The model is calibrated at the yearly frequency. We estimate a VAR(1) for the aggregate state variables using annual data:

$$\log S_{t+1} = \mu_S + \Phi_S \log S_t + \sqrt{\Sigma_S} \epsilon_{t+1}^S. \quad (18)$$

The variables we use are the U.S. GDP growth rate adjusted for CPI inflation (our proxy for the real growth variable Z in the model), the one-year Treasury bill rate as the nominal short rate $r_t^{\$}$, CPI growth rate (a measure of inflation π), and demeaned log house price-GDP ratio computed using the S&P Case-Shiller house price index (HPI) deflated using the CPI. The macroeconomic variables used - the CPI, the real GDP, the real HPI, and the HPI/GDP ratio are plotted in Figure 4.1. The last variable captures the notion of highly persistent but transitory deviations of house prices from the trend of real economic growth represented in the model by the state variable h .

The descriptive statistics for these variables (as well as the 30-year conforming mortgage rate – our empirical proxy for R) and the estimated parameters of the VAR are reported in Table 6. We then approximate the VAR with a discrete-state Markov chain using the method of Tauchen and Hussey (1991). The real growth rate of the economy Z is discretized using 2 points to capture two macroeconomic states for growth. The ‘bad’ state of the economy is denoted by Z^B and is defined as the cases when the economy grows at the low rate and, conversely, the ‘good’ state is denoted Z^G and corresponds to the high growth rate. The short rate $r^{\$}$, the house price process $\tilde{h}$, and the inflation rate process π are discretized each as a 3-state Markov chain. Thus the aggregate state is discretized using a total of 54 grid

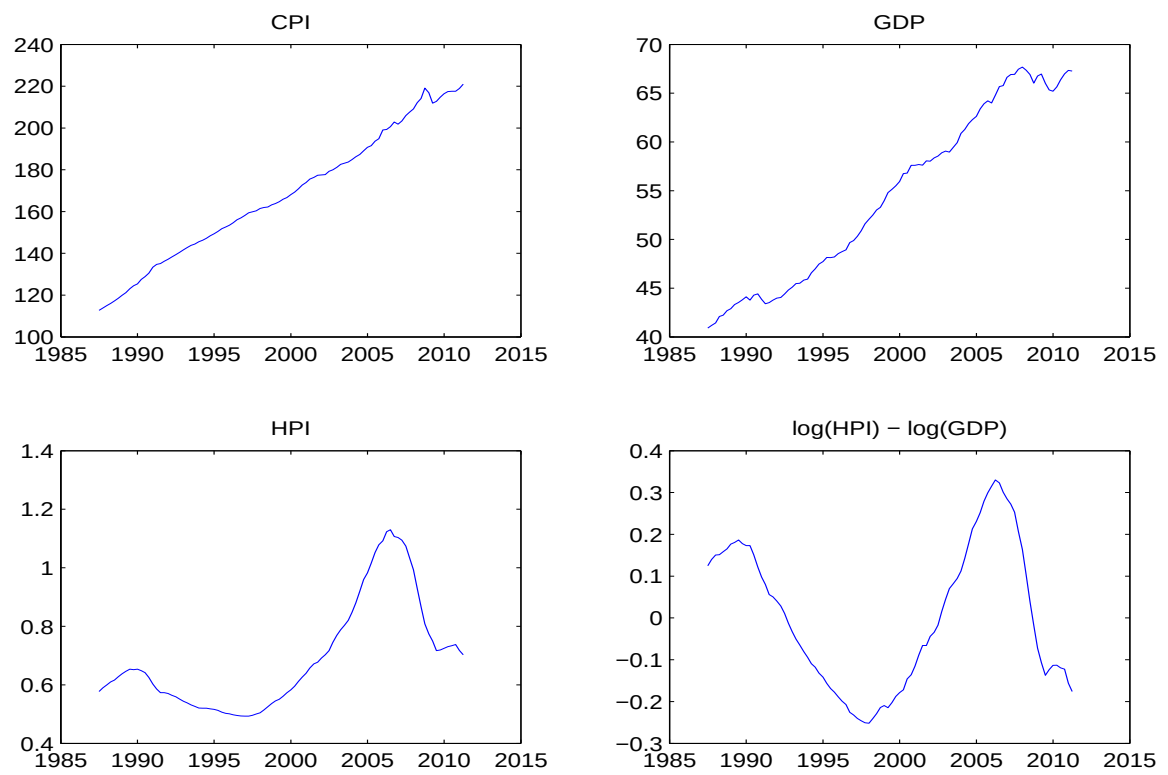


Figure 4: Inflation, real growth, and real house prices

Table 6: Aggregate State Variables

Panel A: Descriptive Statistics

	GDP	r_t^s	CPI	HPI/GDP	R
Mean	2.085	4.414	2.855	0.000	7.308
Std	1.646	2.272	1.275	17.310	1.605
Autocorrelation	0.419	0.724	0.149	0.866	0.828
correlations:					
GDP		0.064	-0.144	-0.153	0.060
r_t^s			0.614	0.104	0.892
CPI				0.429	0.596
HPI/GDP					0.089

Panel B: VAR Parameters

	μ	Φ_s				$\Sigma_s \times 10^{-3}$			
GDP	0.009	0.442	-0.324	0.607	-0.051	0.142	-0.009	-0.013	0.202
r	-0.010	0.495	0.660	0.432	-0.003	-0.009	0.111	0.075	0.100
CPI	0.019	0.187	0.240	-0.219	0.030	-0.013	0.075	0.107	0.304
HPI/GDP	-0.053	2.144	-2.000	3.114	0.837	0.202	0.100	0.304	4.182

Panel C: Mortgage Rate Parameters

κ_0	κ			
	Z	r	π	$\tilde{h}$
0.043	0.016	0.586	0.134	-0.004
(0.002)	(0.050)	(0.051)	(0.092)	(0.012)

points. The choice of the long-run mean of the ratio of house price to income $\bar{H} = 4$ is based on estimates obtained using micro data (in the Survey of Consumer Finances for 2001, a year when the house price to GDP ratio is close to its long-run mean, the average ratio of housing assets to income among homeowners with positive income equals approximately 3.95).

For tractability, we specify the mortgage rate R as an exogenous function of all the aggregate state variables. We choose the following specification,

$$\log R(S) = \kappa_0 + \kappa' \log S. \quad (19)$$

Panel C of Table 6 reports the regression estimates of the coefficients of this relation using the empirical proxies for the state vector S and the mortgage rate R , with the corresponding standard errors. While only the constant and the interest-rate sensitivity are statistically significantly different from zero, we use all of the estimated coefficients in order to capture as much of potential comovement of the mortgage rate with the macroeconomic variables as possible.

The idiosyncratic component of the income process $\tilde{y}_{it}$ is discretized as a Markov chain with 64 grid points. The conditional volatility depends on whether the economy is in the good or bad state, that is we choose a two-state representation of the macroeconomic conditions, following Storesletten, Telmer, and Yaron (2007). We use volatility parameters that are on the higher end of their estimates in order to emphasize the effect of heteroscedasticity on refinancing. In our benchmark calibration, the conditional volatility of the log idiosyncratic income component in the good states (when it is low) is $\sigma_{y,G} = 18\%$, whereas in the bad state, the conditional volatility is high $\sigma_{y,B} = 40\%$. The autocorrelation parameter $\rho_Y = 0.85$ is in the middle of the estimates in the literature (see discussion in section 4.5 below).

Table 7 summarizes the parameters we use for the numerical analysis. The preference parameters (the subjective discount factor $\beta = 0.97$ and the curvature of the utility function $\gamma = 3$) are chosen so that the mean and standard deviation of aggregate consumption growth are close to those in the NIPA data. The mortgage rates are higher than the subjective rate of time preference, so that mortgages are a costly form of borrowing and households prefer to pay down their balances. The cost of refinancing is set so as to generate empirically reasonable average refinancing rates. Based on anecdotal evidence of explicit costs of roughly 2 – 5% paid when refinancing a mortgage loan of average size in addition to non-pecuniary information processing costs and the opportunity cost of time required to process the transaction, we choose a fixed cost of 5% and a proportional cost of 5% (which is somewhat higher than the costs calibrated by Campbell and Cocco (2003)).

Table 7: Parameter Values.

	Parameter	Model	Description
Preference	β	0.97	Subjective discount rate
	γ	3	Risk aversion
	ψ	1.00	Rent as a share of consumption
Institution	τ	25%	Average tax rate
	ξ	80%	House collateral requirement
	$\bar{H}$	4	House price relative to permanent income
	ϕ_0	5%	Fixed cost of issuing new mortgage
	ϕ_1	5%	Proportional cost of issuing new mortgage
	ϕ_2	10%	Proportional cost of buying/selling a house
	ω	5%	Exogenous rate of relocation
	θ	15%	Rate of access back to home-ownership after default
	ζ	50%	default penalty
Income Process	ρ_y	0.85	Autocorrelation of idiosyncratic income component y
	$\sigma_{y,B}$	40%	Volatility of y for Z^B
	$\sigma_{y,G}$	18%	Volatility of y for Z^G

NOTE: The model is calibrated at the yearly frequency.

4.2 Endogenous Aggregate Variables

For the purposes of analyzing the aggregate implications of households' optimal mortgage choices, we consider a cross-section of N households that follow optimal policies. The households are ex ante identical and are subject to an identical time series of aggregate shocks, that is all households face the same interest rates and macroeconomic shocks in the economy. However households are subject to different realizations of their idiosyncratic income shocks over time. We are interested in the behavior of aggregated household variables along the paths of aggregate state vector S_t . The consumption and financial policies of interest are

given by,

$$\begin{aligned}
\text{Aggregate consumption: } C_t &= \frac{1}{N} \sum_{i=1}^N c_{it}, \\
\text{Aggregate liquid assets: } A_t &= \frac{1}{N} \sum_{i=1}^N a_{it}, \\
\text{Aggregate mortgage balance: } B_t &= \frac{1}{N} \sum_{i=1}^N b_{it}, \\
\text{Average mortgage coupon rate: } K_t &= \frac{1}{N} \sum_{i=1}^N k_{it}.
\end{aligned}$$

The refinancing and cash-out policies of interest are defined as follows:

$$\begin{aligned}
\text{Aggregate refinancing rate: } REFI_t &= \frac{1}{N} \sum_{i=1}^N I_{it}^{RF}, \\
\text{Conditional dollar refinancing: } REFI_t^{\$} &= \frac{\sum_{i=1}^N b_{it+1} I_{it}^{RF}}{\sum_{i=1}^N I_{it}^{RF}}, \\
\text{Conditional dollar cash-out: } CASHOUT_t^{\$} &= \frac{\sum_{i=1}^N (b_{it+1} - b_{it}) I_{it}^{RF}}{\sum_{i=1}^N I_{it}^{RF}}.
\end{aligned}$$

The aggregate repayment behavior - i.e. the pay-down of mortgage balances - is defined as follows:

$$\begin{aligned}
\text{Aggregate repayment rate: } REP_t &= \frac{1}{N} \sum_{i=1}^N I_{it}^{RP}, \\
\text{Conditional dollar repayment: } REP_t^{\$} &= \frac{\sum_{i=1}^N (b_{it} - b_{it+1}) I_{it}^{RP}}{\sum_{i=1}^N I_{it}^{RP}}.
\end{aligned}$$

4.3 Simulations

The household problem is solved numerically and simulated data are generated using the optimal policies. A cross-section of $N = 10,000$ households is considered and the various aggregate quantities defined above are calculated along the time path of $T = 200$ (annual) periods.

Our simulation strategy is as follows. We start the simulations by randomly drawing triplets (a_i, b_i, m_i) over the state space for all N households in the cross-section. At every time period, we draw a pair (ω_i, θ_i) for each household in the cross-section. This will allow us to know whether a particular home-owner is subject to an exogenous move, or if a particular post default renter is allowed back into the home-ownership market. In other words, these random draws will tell us the feasible set of choices for all households at all times.

We replicate the regressions that we ran in the data by running a number of regressions of the aggregate refinancing rate $REFI_t$ on the rates R_t , r_t , the macroeconomic growth rate Z_t , and the house price h_t . We use several model specifications in order to isolate the various effects at work. The benchmark calibration features a baseline level of stochastic volatility of income shocks. The second specification features homoscedasticity in income shocks, i.e. $\sigma_{y,B} = \sigma_{y,G} = 25\%$, and the average volatility is set to the average volatility in the benchmark case. The third specification keeps heteroscedasticity in the income process and doubles the volatility of the benchmark case in the bad state, i.e. $\sigma_{y,B} = 80\%$ is doubled. The fourth specification has again homoscedastic income shocks, but the average volatility is set to the (higher) level of average volatility of specification three ($\sigma_{y,B} = \sigma_{y,G} = 35\%$). Specifications two and four of labor income process are closest to that estimated by Heaton and Lucas (1996) in that they feature high but constant volatility of labor income risk (but higher persistence). These specifications will allow us to understand the difference between the effect of the overall level of volatility and the effect of high volatility in the bad state alone.

4.4 Refinancing Behavior

4.4.1 Aggregate Behavior

Table 8 reports averages of the aggregated variables computed using the simulated data. The table shows that households in the benchmark case experience less frequent refinancing and repayment and slightly lower mortgage balances than in the homoscedastic specification

(3). However when they in fact refinance or repay the principal, they do so in similar magnitudes across all specifications, with cash-outs equal on average to 15% of home value and about 65% of annual income. Another distinguishing feature is that households tend to carry slightly higher liquid assets, consistent with a precautionary motive. The benchmark specification represents a riskier world from the standpoint of the model household than specification (3) that features homoscedasticity. In a riskier world, households will tend to accumulate more cash on hand as a precautionary buffer stock, and thus be less likely to have to resort to refinancing in order to self-insure against adverse idiosyncratic labor income shocks. Given the spread between the borrowing and lending rates, carrying both cash balances and mortgage debt is costly, and therefore a stronger precautionary saving motive implies that households keep lower mortgage balances by repaying their debt more quickly. The strength of the precautionary saving motive is therefore key for understanding quantitative features of the model, in the sense that it determines the ex-ante behavior of mortgage borrowers. This is corroborated by the result for the riskier specifications (2) and (4) in which households maintain larger holdings of liquid assets (about 1.5 times annual income) but also have to resort to refinancing to smooth consumption more often, yielding roughly the same refinancing activity as in the benchmark case.

4.4.2 Behavior in the Cross-Section

In order to understand the refinancing behavior in the aggregate, it is important to understand the refinancing and repayment behavior at the household level. To accomplish this, we need to understand which households refinance and repay their mortgage. Because all households are ex-ante identical, they differ by their history of shocks, which in turn affect their level of liquid assets and mortgage balance. We use the simulated data to compute average refinancing and repayment rates, as well as the dollar amounts, across two dimensions: (i) level of period income relative to aggregate income (y_i/pY), and (ii) liquid assets to income ratio (a_i/pY).

Table 8: Summary Statistics.

Model Specification	(1)	(2)	(3)	(4)
Comparative Statics on $\sigma_{y,G}$	0.18	0.18	0.25	0.35
Comparative Statics on $\sigma_{y,B}$	0.40	0.80	0.25	0.35
<u>Aggregate Real Consumption:</u>				
Aggregate Consumption Growth $\mu(\Delta \log C)$	2.1%	2.2%	2.1%	2.1%
Aggregate Consumption Growth $\sigma(\Delta \log C)$	2.2%	2.3%	1.8%	1.5%
<u>Average Consumption and Financial Policies:</u>				
Consumption to Income c/pY	0.72	0.74	0.72	0.71
Income Growth $\mu(\Delta \log y)$	2.2%	2.2%	2.2%	2.1%
Income Growth $\sigma(\Delta \log y)$	32.6%	53.6%	26.8%	36.6%
Consumption Growth $\mu(\Delta \log c)$	2.1%	2.1%	2.1%	2.0%
Consumption Growth $\sigma(\Delta \log c)$	24.2%	24.9%	23.3%	25.3%
Liquid Asset Holdings to Income a/pY	1.14	1.58	0.76	1.42
Mortgage Balance to Income b/pY	0.42	0.43	0.50	0.42
Mortgage Balance to House Value b/H	0.10	0.10	0.12	0.10
Mortgage Rate k	6.72%	6.88%	6.70%	6.66%
<u>Refinancing:</u>				
<i>REFI</i>	15.40%	16.48%	16.46%	15.38%
Conditional \$ <i>REFI</i> to Income	1.28	1.25	1.40	1.30
Conditional \$ <i>REFI</i> to House Value	0.32	0.31	0.34	0.32
Conditional \$ Cash-out to Income	0.63	0.61	0.68	0.64
Conditional \$ Cash-out to House Value	0.15	0.15	0.16	0.16
<u>Repayment:</u>				
<i>REP</i>	23.02%	22.30%	26.96%	23.23%
Conditional \$ <i>REP</i> to Income	0.38	0.40	0.36	0.39
Conditional \$ <i>REP</i> to House Value	0.09	0.09	0.08	0.09
<u>New Home Loan:</u>				
<i>NEW LOAN</i>	0.01%	0.01%	0.01%	0.01%
Conditional \$ <i>NEW LOAN</i> to Income	2.52	2.39	2.71	2.87
Conditional \$ <i>NEW LOAN</i> to House Value	0.63	0.62	0.69	0.74
<u>Ownership Status:</u>				
Percentage of Home-owner	96.30%	98.09%	97.00%	96.00%
Percentage of Renter	3.67%	1.89%	2.99%	3.94%

NOTE: Summary statistics of the simulated data, for different model specifications.

Figure 4.4.2 plots averages by households sorted and grouped into 5 bins. The upper panel shows the results for the sort over income, while the lower panel shows the results for the sort over liquid assets. It is clear from these graphs that the households who refinance are those who experience very low income and have very low level of liquid assets. In contrast, households repay their mortgage at a higher rate when they achieve high levels of income. Similarly households repay higher dollar amounts when they have higher stock of liquid assets. All of these qualitative results are consistent with the consumption smoothing motive: households repay their costly mortgage balance in good times -high level of income and assets- and refinance to pull out home equity in order to increase consumption in bad times -low level of income and assets-.

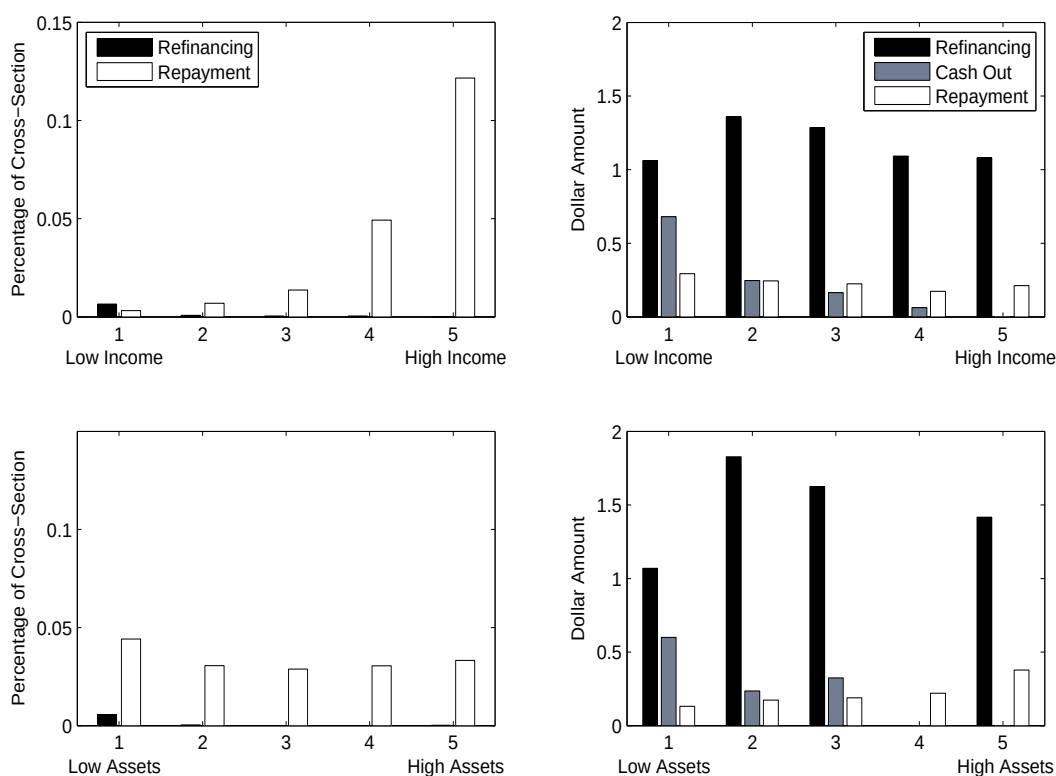


Figure 5: Refinancing and repayment rates (on the left panels), and dollar refinancing, cashout and repayment (on the right panels).

4.4.3 Aggregate Refinancing Activity

Table 9 reports the results for the regressions ran in the simulated data for each of the model specifications for the aggregate levels of refinancing (average number of refi loans) on the aggregate state variables. The key empirical relationship holds in the model: lower mortgage rates R imply more refinancing. Since in the model the mortgage rate is driven primarily by the short rate r , when the latter variable is included in the regressions it drives out the mortgage rate, unlike in the data where the variation in the mortgage rate is less well captured by the short rate.

As in the data, refinancing activity in the model is counter-cyclical, as it is negatively related to the aggregate labor income, captured by the negative coefficient on the rate of economic growth Z (after controlling for the mortgage rate or the short rate). Also, the coefficient of refi on the house price growth variable ΔH is positive as it is in the data, consistent with the fact that higher levels of house prices help relax the collateral constraint.

As demonstrated in Table 8, refinancing activity is higher in the benchmark case, and the lowest in the model specification that is the most risky (i.e. where income is heteroscedastic and most volatile). This is consistent with the precautionary motive: there is less refinancing activity when mortgage rates are falling when the world is very risky, since in such a world household pay down mortgages quickly and accumulate a buffer stock of liquid assets. Indeed, the model produces less sensitivity of refi to interest rates and the other macro variables in the riskier specifications (2) and (4). At the same time, the homoscedastic specification (2) with the same average level of idiosyncratic risk as the benchmark also generates much lower sensitivity to the macroeconomic shock Z , consistent with the view that the bulk of the cyclical behavior of refinancing is driven by the increasing dispersion of idiosyncratic income shocks experiences during downturns.

These quantitative experiments have enabled us to understand the effect of state-dependent conditional mean and volatility on households aggregate refinancing activity. An increase in the riskiness of idiosyncratic income leads risk averse households to use their home equity

Table 9: Regressions - simulated data.

Model Specification	R	r	Z	ΔH	R^2
(1) Benchmark: Heteroskedastic	-0.67 (0.15)				0.09
	-0.09 (0.32)	-0.49 (0.25)			0.11
	-0.58 (0.14)		-0.79 (0.12)		0.25
	-0.04 (0.29)	-0.46 (0.22)	-0.78 (0.12)		0.27
	-0.46 (0.13)		-1.03 (0.13)	0.08 (0.02)	0.33
(2) Heteroskedastic + High Volatility	-0.32 (0.16)				0.02
	0.98 (0.40)	-1.09 (0.31)			0.08
	-0.38 (0.15)		-0.63 (0.13)		0.12
	0.80 (0.39)	-0.99 (0.30)	-0.60 (0.13)		0.17
	-0.35 (0.15)		-0.72 (0.14)	0.03 (0.02)	0.13
(3) Homoskedastic	-0.87 (0.15)				0.15
	0.43 (0.36)	-1.07 (0.28)			0.21
	-0.86 (0.14)		-0.30 (0.13)		0.17
	0.45 (0.36)	-1.08 (0.27)	-0.30 (0.12)		0.24
	-0.85 (0.15)		-0.34 (0.14)	0.01 (0.02)	0.18
(4) Homoskedastic + High Volatility	-0.24 (0.12)				0.02
	0.51 (0.31)	-0.61 (0.24)			0.05
	-0.27 (0.12)		-0.19 (0.11)		0.04
	0.44 (0.31)	-0.57 (0.24)	-0.16 (0.10)		0.07
	-0.24 (0.12)		-0.26 (0.11)	0.03 (0.02)	0.06

NOTE: Regressions results for refinancing activity on interest rates and state of the economy, using simulated data, for different model specifications.

with more caution. When the world is more uncertain, households will tend to hold more liquid assets and reduce their mortgage balance. This behavior also leads them to be less responsive to a decrease in mortgage rates. At the same time, the counter-cyclical volatility of idiosyncratic labor income risk is key for generating highly counter-cyclical refinancing.

4.5 The role of persistence in idiosyncratic shocks

There is some debate in the literature on the degree of persistence of idiosyncratic labor income shocks and its implications for asset pricing and macroeconomics. Persistence is key for consumption smoothing: e.g., Constantinides and Duffie (1996) postulate a process for idiosyncratic labor income that features only permanent (and heteroscedastic) shocks that implies no smoothing at all. In contrast, Heaton and Lucas (1996) estimate the autocorrelation of idiosyncratic labor income as low as 0.5 implying that households are able to self-insure almost perfectly by accumulating buffer stocks of liquid assets in good times, then drawing them down and borrowing in bad times, repaying the loans when good times return. We investigate the implications of different persistence estimates for refinancing behavior.

We consider a range of persistence parameters ρ_y between zero (entirely transitory shocks) and 0.95 (extremely persistent shocks, as estimated by Storesletten, Telmer, and Yaron (2004)). Table 10 displays the summary statistics for these alternative parameterizations, holding all other parameters constant as in the benchmark calibration. As is evident from this table, higher persistence implies higher idiosyncratic consumption volatility, varying from below 20% when $\rho_y = 0$ to almost 26% for $\rho_y = 0.95$, as it is much easier for households to smooth transitory shocks than persistent shocks. Households facing more persistent shocks accumulate substantially more liquid assets due to the precautionary motive, since their lifetime income is much riskier (even though the conditional volatility of labor income shocks is the same, the long-run volatility is much higher). Increasing persistence from 0.85 to 0.95 almost doubles the average stock of liquid assets relative to permanent income, from just above 1 to over 2. At the same time, average mortgage balances are lower. At the same

Table 10: Summary Statistics - Varying Persistence

Model Specification	(5)	(6)	(1)	(7)	(8)
Persistence of idiosyncratic shocks ρ_y	0	0.5	0.85	0.9	0.95
<u>Aggregate Real Consumption:</u>					
Aggregate Consumption Growth $\mu(\Delta \log C)$	1.9%	2.1%	2.1%	2.2%	2.3%
Aggregate Consumption Growth $\sigma(\Delta \log C)$	2.7%	2.4%	2.2%	2.1%	2.0%
<u>Consumption and Financial Policies:</u>					
Consumption to Income c/pY	0.69	0.70	0.72	0.72	0.71
Income Growth $\mu(\Delta \log y)$	2.1%	2.2%	2.2%	2.2%	2.3%
Income Growth $\sigma(\Delta \log y)$	45.7%	36.5%	32.6%	31.5%	30.3%
Consumption Growth $\mu(\Delta \log c)$	1.9%	2.1%	2.1%	2.2%	2.2%
Consumption Growth $\sigma(\Delta \log c)$	19.8%	20.6%	24.2%	24.8%	25.8%
Liquid Asset Holdings to Income a/pY	0.36	0.36	1.14	1.56	2.12
Mortgage Balance to Income b/pY	1.51	1.02	0.42	0.36	0.34
Mortgage Balance to House Value b/H	0.37	0.25	0.10	0.09	0.08
Mortgage Rate k	6.56%	6.62%	6.72%	6.78%	6.62%
<u>Refinancing:</u>					
<i>REFI</i>	30.48%	27.74%	15.40%	14.12%	13.23%
Conditional \$ <i>REFI</i> to Income	2.04	1.64	1.28	1.24	1.24
Conditional \$ <i>REFI</i> to House Value	0.50	0.40	0.32	0.30	0.30
Conditional \$ Cash-out to Income	0.87	0.76	0.63	0.62	0.63
Conditional \$ Cash-out to House Value	0.21	0.19	0.15	0.15	0.15
<u>Repayment:</u>					
<i>REP</i>	61.70%	47.69%	23.02%	20.56%	19.68%
Conditional \$ <i>REP</i> to Income	0.32	0.35	0.38	0.39	0.40
Conditional \$ <i>REP</i> to House Value	0.08	0.08	0.09	0.09	0.09
<u>New Home Loan:</u>					
<i>NEW LOAN</i>	0.00%	0.00%	0.01%	0.01%	0.01%
Conditional \$ <i>NEW LOAN</i> to Income	2.94	2.86	2.52	2.79	2.79
Conditional \$ <i>NEW LOAN</i> to House Value	0.70	0.71	0.63	0.68	0.68
<u>Ownership Status:</u>					
Percentage of Home-owner	99.09%	99.17%	96.30%	95.58%	93.36%
Percentage of Renter	0.90%	0.81%	3.67%	4.41%	6.63%

NOTE: Summary statistics of the simulated data, for different model specifications.

time, there is much less refinancing when shocks are persistent, since cash-out loans need to be repaid which is harder when adverse shocks are permanent. Thus, with transitory shocks households self-insure by accessing housing collateral more often and cashing out more home equity in relation to their income, which leads to higher average mortgage balances and higher rates of loan repayment.

We also repeat the regression experiments on the simulated data for different persistence parameters. These results are reported in Table 11. As persistence increases from fully transitory shocks - specification (5) - to very persistent shocks - specification (8) - the sensitivity of refinancing to aggregate economic growth rate Z decreases substantially in magnitude, consistently with the fact that persistent shocks that have greater dispersion in bad times are also more difficult to self-insure against. At the same time, the sensitivity of refinancing to house prices increases slightly, indicating that households are more willing to borrow if they have a large enough cushion of home equity remaining, possibly for the fear of having to default if income payments become too onerous and house prices fall, as analyzed by Campbell and Cocco (2010). The pattern of interest rate sensitivities is non-monotonic however, suggesting that low interest rates are less important both when shocks are transient (so that borrowing for consumption-smoothing reasons can be repaid quickly and a higher interest rate is less thus costly) and when they are very persistent (and there is less refinancing overall).

5 Conclusion

We document counter-cyclical variation of aggregate mortgage refinancing and explore a model of household behavior in which mortgage refinancing is driven by both time-varying interest rates and by consumption-smoothing in the face of idiosyncratic labor income risk. The model is able to replicate the main features of the counter-cyclical refinancing activity. It also highlights the importance for understanding the cyclical dynamics of idiosyncratic

Table 11: Regressions - simulated data (varying persistence).

Model Specification	R	r	Z	ΔH	R^2
(5)	-0.68				0.01
	(0.43)				
	0.28	-0.84			0.02
	(0.88)	(0.68)			
	-0.86		-1.90		0.15
	(0.41)		(0.34)		
	0.36	-1.08	-1.94		0.16
	(0.82)	(0.63)	(0.34)		
	-0.83		-2.00	0.03	0.15
	(0.41)		(0.39)	(0.05)	
(6)	-1.35				0.08
	(0.33)				
	0.68	-1.78			0.12
	(0.73)	(0.57)			
	-1.33		-1.23		0.19
	(0.31)		(0.24)		
	0.83	-1.88	-1.25		0.23
	(0.69)	(0.54)	(0.23)		
	-1.27		-1.38	0.04	0.19
	(0.32)		(0.28)	(0.03)	
(7)	-0.61				0.10
	(0.13)				
	-0.00	-0.52			0.12
	(0.32)	(0.25)			
	-0.64		-0.60		0.24
	(0.12)		(0.10)		
	0.09	-0.62	-0.62		0.26
	(0.30)	(0.23)	(0.10)		
	-0.57		-0.76	0.06	0.30
	(0.12)		(0.11)	(0.01)	
(8)	-0.50				0.07
	(0.12)				
	-0.16	-0.31			0.09
	(0.22)	(0.17)			
	-0.52		-0.25		0.10
	(0.12)		(0.11)		
	-0.21	-0.28	-0.24		0.11
	(0.22)	(0.17)	(0.10)		
	-0.38		-0.52	0.08	0.24
	(0.12)		(0.11)	(0.01)	

NOTE: Regressions results for refinancing activity on interest rates and state of the economy, using simulated data, for different model specifications.

labor income risk for evaluating the quantitative features of refinancing behavior.

Our model can also be used to study the aggregate consumption implications of the impediments to refinancing. Refinancing is difficult when house prices fall, or when banks are in distress. These tend to coincide with bad income/productivity shocks. When markets are incomplete, this can severely hinder households' ability to smooth consumption or hedge against deflation risk, and exacerbate recessions.

In order to evaluate the equilibrium effect of the counter-cyclical refinancing we could endogenize mortgage rates by introducing an exogenous stochastic discount factor calibrated to match the term-structure interest rates. It could be used to price a menu of mortgage contracts (consisting of coupon rates and loan-to-value ratios) conditional on household characteristics. In that we could build on the analysis of Dunn and Spatt (2005) and Longstaff (2004) to the setting where borrower's decisions are explicitly affected by labor income fluctuations. This would allow us to evaluate the welfare impact of refinancing costs by incorporating the equilibrium response of mortgage spreads to slower prepayment speeds.

Potential questions that could be addressed within this framework include: was 2001 recession mild because high house prices allow households to smooth consumption, given the low interest rate environment? Can the refinancing boom of early 2000's, widely seen as contributing to the financial crisis (e.g. Khandani, Lo, and Merton (2009), Mian and Sufi (2010)) be attributed to the persistent dispersion of labor income and its slow aggregate growth following the recession - the "jobless recovery"? Can the contribution of each effect - low interest rates, high house prices, and macroeconomic conditions - be separately identified? We plan to address these questions in the future.

Appendix A – Stationary Reformulation of the Household Recursive Problems

Let the household utility be CRRA, $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$, then we can rescale the problem with respect to the permanent aggregate income Y_t and the price level p_t in order to make it stationary. Define the rescaled variables as follows,

$$a_{i,t+1} = p_t Y_t \tilde{a}_{i,t+1}, \quad b_{i,t+1} = p_t Y_t \tilde{b}_{i,t+1}, \quad \text{and} \quad c_{it} = p_{t-1} Y_{t-1} \tilde{c}_{it},$$

and the value functions as,

$$U_{it}^j = \left(\frac{Y_{t-1} p_{t-1}}{p_t} \right)^{1-\gamma} \tilde{U}_{it}^j, \quad \text{with } j \in \{h, r, d, hh, hr, hd, rh\}.$$

Then by taking advantage of homogeneity of the utility function, the original problem in the home-owner state can be restated as,

$$\begin{aligned} \tilde{U}_i^h(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) &= \max_{\tilde{a}_i', \tilde{b}_i', I_i^{RF}} u(\tilde{c}_i) \\ &+ \beta \mathbb{E} \left[\left(\frac{\pi Z}{\pi'} \right)^{1-\gamma} \left(\omega \max \left(\tilde{U}_i^{h'}, \tilde{U}_i^{hr'}, \tilde{U}_i^{hd'} \right) + (1-\omega) \max \left(\tilde{U}_i^{hh'}, \tilde{U}_i^{hr'}, \tilde{U}_i^{hd'} \right) \right) \right], \end{aligned} \quad (20)$$

subject to,

$$\begin{aligned} \tilde{c}_i + \frac{\pi Z \tilde{a}_i'}{1 + (1-\tau)r^s} + \tilde{b}_i &= (1-\tau)(\pi Z \tilde{y}_i - k_i \tilde{b}_i) + \tilde{a}_i + \pi Z \tilde{b}_i' - \pi Z(\phi_0 + \phi_1 \tilde{b}_i') I_i^{RF}, \\ k_i' &= k_i (1 - I_i^{RF}) + R I_i^{RF}, \\ (\pi Z \tilde{b}_i' - \tilde{b}_i) (1 - I_i^{RF}) &\leq 0, \\ (\tilde{b}_i' - \xi \bar{H} \tilde{h}) I_i^{RF} &\leq 0, \\ \tilde{a}_i, \tilde{c}_i, \tilde{b}_i' &\geq 0. \end{aligned}$$

When the household is not moving, the rescaled value function is defined as,

$$\tilde{V}_i^h(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) = \max \left(\tilde{U}_i^h(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i), \tilde{U}_i^{hr}(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i), \tilde{U}_i^{hd}(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) \right), \quad (21)$$

when the household is moving, the rescaled value function is defined as,

$$\tilde{V}_i^h(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) = \max \left(\tilde{U}_i^{hh}(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i), \tilde{U}_i^{hr}(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i), \tilde{U}_i^{hd}(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) \right), \quad (22)$$

The rescaled household problem in the post default renter state is given by,

$$\tilde{V}_i^d(\tilde{a}_i, \tilde{s}_i) = \max_{\tilde{a}_i'} (1+\psi) u(\tilde{c}_i) + \beta \mathbb{E} \left[\left(\frac{\pi Z}{\pi'} \right)^{1-\gamma} \left((1-\theta) \tilde{U}_i^{re}(\tilde{a}_i', \tilde{s}_i') + \theta \max \left(\tilde{U}_i^{rh}(\tilde{a}_i', \tilde{s}_i'), \tilde{U}_i^r(\tilde{a}_i', \tilde{s}_i') \right) \right) \right], \quad (23)$$

subject to,

$$\begin{aligned} (1+\psi) \tilde{c}_i + \frac{\pi Z \tilde{a}_i'}{1 + (1-\tau)r_t^s} &= (1-\tau)\pi Z \tilde{y}_i + \tilde{a}_i, \\ \tilde{a}_i, \tilde{c}_i &\geq 0. \end{aligned}$$

When in the post default renter state, the rescaled value function if becoming a home-owner is available is given by,

$$\tilde{V}_i^d(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) = \max \left(\tilde{U}_i^{rh}(\tilde{a}_i, \tilde{s}_i), \tilde{U}_i^r(\tilde{a}_i, \tilde{s}_i) \right), \quad (24)$$

or if the home-owner-ship option is unavailable,

$$\tilde{V}_i^d(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) = \tilde{U}_i^d(\tilde{a}_i, \tilde{s}_i). \quad (25)$$

The rescaled household problem in the post selling renter state is given by,

$$\tilde{U}_i^r(\tilde{a}_i, \tilde{s}_i) = \max_{\tilde{a}_i'} (1+\psi) u(\tilde{c}_i) + \beta \mathbb{E} \left[\left(\frac{\pi Z}{\pi'} \right)^{1-\gamma} \max \left(\tilde{U}_i^{rh}(\tilde{a}_i', \tilde{s}_i'), \tilde{U}_i^r(\tilde{a}_i', \tilde{s}_i') \right) \right], \quad (26)$$

subject to,

$$\begin{aligned} (1 + \psi) \tilde{c}_i + \frac{\pi Z \tilde{a}'_i}{1 + (1 - \tau)r^\$} &= (1 - \tau)\pi Z \tilde{y}_i + \tilde{a}_i, \\ \tilde{a}_i, \tilde{c}_i &\geq 0. \end{aligned}$$

When in the post selling renter state, the rescaled value function is given by,

$$\tilde{V}_i^r(\tilde{a}_i, \tilde{b}_i, k_i, \tilde{s}_i) = \max \left(\tilde{U}_i^{rh}(\tilde{a}_i, \tilde{s}_i), \tilde{U}_i^r(\tilde{a}_i, \tilde{s}_i) \right). \quad (27)$$

The rescaled transition problem for the household from the renter to the home-owner state is given by,

$$\tilde{U}_i^{rh}(\tilde{a}_i, \tilde{s}_i) = \max_{\tilde{a}'_i, \tilde{b}'_i} (1 + \psi) u(\tilde{c}_i) + \beta \mathbb{E} \left[\left(\frac{\pi Z}{\pi'} \right)^{1-\gamma} \tilde{U}_i^h(\tilde{a}'_i, \tilde{b}'_i, R, \tilde{s}_i) \right], \quad (28)$$

subject to,

$$\begin{aligned} (1 + \psi) \tilde{c}_i + \frac{\pi Z \tilde{a}'_i}{1 + (1 - \tau)r^\$} + \pi Z \bar{H} \tilde{h} &= (1 - \tau)\pi Z \tilde{y}_i + \tilde{a}_i + \pi Z \tilde{b}'_i - \pi Z(\phi_0 + \phi_1 \tilde{b}'_i), \\ \tilde{b}'_i &\leq \xi \bar{H} \tilde{h}, \\ \tilde{a}_i, \tilde{c}_i, \tilde{b}'_i &\geq 0. \end{aligned}$$

The new state vector $\tilde{s}_i \equiv (\tilde{y}_i, r^\$, Z, \tilde{h}, \pi)$. In contrast to the original (nominal) formulation of the problem where the processes y_i and H are growing over time, the processes $\tilde{y}_i$ and $\tilde{h}$ in the rescaled problems are stationary.

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